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(54) Title: IMPROVED MULTILAYER OPTICAL MEDIUM FOR NEAR-FIELD OPTICAL RECORDING AND READING

DLC Layer
Conductive Power-Mitigating Layer
Capping Power-Mitigating Layer
MO Layer
Reflector
Substrate

(57) Abstract

    A magnetooptical recording medium including embodiment shown in figure 6, where a substrate is provided with a reflective layer, a magnetooptic recording layer, an insulating power mitigating layer, a heat conductive power mitigating layer and a topmost layer which may be made of a material such as diamond like carbon (DLC). This medium structure reduces the thermal burden transferred from the recording layer to an optical head (140) which floads within a wavelength of the optical recording medium (150), such as that shown in figure 1 when recorded is perfomed by both preventing heat conduction to the head using the topmost layer and the heat insulating layer and conducting any heat generated through the use of the reflective layer and the heat conductive power mitigating layer away from the optical head.

IMPROVED MULTILAYER OPTICAL MEDIUM FOR NEAR-FIELD OPTICAL RECORDING AND READING

5   FIELD OF THE INVENTION
        The present invention generally relates to optical
recording and reading, and more particularly, to a near-
field optical storage system and a multilayer optical
medium.

10   BACKGROUND
        Optical storage can be used to achieve high areal
density data storage by using a tightly focused laser
beam. For example, electro-optical data storage systems
based on magneto-optical materials can be configured to
15 produce an areal data density of up to or higher than
about one gigabit per square inch. A monochromatic
optical beam can be focused to a small spot by using an
optical head with a large numerical aperture. This can
produce a minimum spot size on the order of one
20 wavelength due to the diffraction limit. The areal
density of an optical storage device, in principle, is
limited by this diffraction-limited spot size. The areal
data density may be increased by reducing the spot size
of a beam within the diffraction limit by using light
25 sources of short wavelengths, such as lasers toward the
blue end of the optical spectrum.
        For a given wavelength, the area data density of
an optical storage system can be increased by focusing an
optical beam onto a flat surface of a solid transparent
30 material with a high refractive index that is implemented
in the optical head. The diffraction-limited focused
spot size is hence reduced by a factor of the refractive
index compared to the spot size in air.

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In particular, a near-field configuration between the optical head and the optical medium may be formed by placing the optical head near the medium surface at a distance on the order of or less than one wavelength to
5 effect evanescent optical coupling therebetween.

For example, the medium surface and the flat surface of the solid material may be typically spaced closer than one wavelength. U.S. Patent No. 5,125,750 to Corle and Kino discloses a near-field optical recording
10 system based on a solid immersion lens.

In a near-field configuration, the numerical aperture of the optical head can be greater than unity which is beyond the diffraction limit in air.

SUMMARY

15   The present invention is embedded in an electro-optical data storage system in a near-field configuration. This system includes an optical train which has an optical head for coupling optical energy to and from a recording layer in an optical storage medium.
20 In a preferred embodiment, the optical head is spaced from the surface of the medium by an air gap typically less than one wavelength in thickness. Hence, the optical coupling between the optical head and the optical medium is effected by both the optical propagation and
25 evanescent coupling through the air gap.

An optical beam from the optical head is focused onto the medium and causes localized heating at and near the focused spot. This localized heating can modify certain properties of the interface of the optical head
30 and the optical medium and thereby can cause distortion in the received signals. This may adversely affect the performance of the system. The recognition of such a problem is one aspect of the invention.

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Another aspect of the invention is a multilayer
structure of the optical storage medium that reduces the
adverse effects of the localized heating. The multiple
layers are preferably configured to substantially confine
5   the heat within or near the recording layer to reduce the
temperature change at the surface of the medium close to
the optical head.

In one embodiment, a special capping layer may be
formed on the medium surface to thermally insulate the
10   optical head and the medium. The capping layer may be
formed of a thick and optically transparent material with
a low thermal conductivity. This reduces the thermal
feedback from the medium to the optical head caused by
the localized heating. A material comprising at least
15   one of a diamond-like-carbon material, silicon nitride,
silicon dioxide and others, for example, can be used to
form the capping layer.

In another embodiment, one or more heat-
dissipating layers having high thermal conductivities may
20   be used to reduce the amount of thermal energy conducted
to the medium surface near the optical head. Such a
heat-conducting layer may be formed in the medium either
between the optical head and the recording layer or on
the other side of the recording layer. When such a
25   thermally conductive layer is formed between the
interface and the recording layer, an optically
transparent material, such as a layer of aluminum
nitride, a thin transparent film of gold or silver, can
be used.

30   In yet another embodiment, one or more capping
layers may be combined with one or more heat-dissipating
layers to further reduce the surface heating near the
optical head.

These and other aspects and advantages of the
35   present invention will become more apparent in light of

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the following detailed description, the accompanying drawings, and the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic illustration of a simplified
5   optical train of an optical storage system according to one embodiment of the invention.

FIGs. 2A and 2B are plots of measured data showing the effect of the laser power dependent signal in the near-field system shown in FIG. 1.

10   FIG. 3A is a chart showing the effect of a SiN capping layer formed on several glass substrate disks.

FIG. 3B is a diagram illustrating the structure of the disks with a capping layer that are used to obtain data in FIG. 3A.

15   FIG. 4 is a chart showing the correlation between measured threshold values of the laser power dependent signal and calculated surface temperature rise after 500 ns of laser illumination of 1 mW for various stacks of different underlayers and thermal conductivities.

20   FIGs. 5A and 5B are charts showing the correlation between measured threshold values for the laser power dependent signal and calculated surface temperature rise after 500 ns of laser illumination of 1 mW for SiO_2 and SiN stacks, respectively.

25   FIG. 6 is a diagram showing a multilayer optical medium having two different power-mitigating layers: a capping layer and a thermal conductive layer.

FIG. 7A is a chart showing the calculated surface temperatures after 500 ns of illumination of a laser beam
30   at 1 mW for various disks having a magneto-optical ("MO") recording layer based on a stack of APO/AlTi(50)/MO(20)/SiN(40)/DLC(10) and another stack of APO/AlTi(50)/SiN(20)/MO(20)/SiN(120)DLC(10).

FIG. 7B is a chart showing the calculated surface
35   temperature after 500 ns of illumination of laser power

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at 1 mW for a multilayer stack having a structure of
APO/AlTi/MO(20)/SiN(40)/DLC(10) with different Ti content
and different thickness values of the AlTi underlayer.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

5   FIG. 1 shows an optical train 100 of an optical
storage system in accordance to an embodiment. A light
source 102 such as a laser produces a beam at a specified
wavelength for recording and retrieving data. An optical
medium 150 (e.g., a disk) is configured to include a
10 recording layer 152 (e.g., formed of a magneto-optical
material or phase-changing material) for data storage.
Data is spatially distributed and stored in the recording
layer 152 by a suitable encoding method. Various
encoding schemes are known in the art. The optical
15 medium 150 may be a removable medium or a fixed medium
which is held and supported by a medium holder.

          An optical beam from the light source 102 is
collimated by an optical collimator 104 and then
projected to an optical head 140 by a relay lens 110 and
20 an imaging lens 120. The optical head 140 has an
objective lens 142 and a near-field lens 144 to couple
the beam to the optical medium 150.

          The near-field lens 144 is preferably made of a
high-index optical material to produce a large effective
25 numerical aperture ("NA"), i.e., NA = $n\sin\theta_0$, where n is
the refractive index of the near-field lens 144 and θ_0 is
the maximum ray angle from the lens 144 to the focus
point. For example, a solid immersion lens ("SIL"), a
graded index lens ("GRIN lens") or a "Gradium lens" may
30 be used as the near field lens 144 to achieve an NA up to
and greater than unity. FIG. 1 shows a hemispherical SIL
as an example of the near-field lens 144.

          The near-field lens 144 and the optical medium 150
are spaced from each other by an air gap less than one

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wavelength of the light produced by light source 102.
This is known as a "near-field" configuration. Optical
energy is coupled between the near-field lens 144 and the
optical medium 150 by both light propagation and

5 evanescent waves through the thin air gap therebetween.
In a near-field optical disk drive, the optical head 140
can be made compact and light-weight so that it can be
suspended over the optical medium 150 (i.e., an optical
disk). In operation, the optical medium 150 is spinning

10 and the optical head is floating over the disk at a
height less than one wavelength (e.g., in a range from
about 50 nm to about 200 nm).

A beam splitter 106 can be disposed to guide a
reflected beam from the optical medium 150 to a detection

15 module 108 which has detectors for both data extraction
and beam tracking. The output beam from the light source
102 may be may be polarized and the beam splitter 106 may
be a polarizing prism in order to direct nearly all
reflected beam to the detection module 108 by using a

20 polarization rotator (e.g., a quarter wave plate) between
the beam splitter 106 and the optical medium 150).

Certain implementations of the optical train 100
in FIG. 1 and their operations are described in U.S.
Patent Application No. 08/846,916, "Electro-optical

25 storage system with flying head for near-field recording
and reading", filed on April 29, 1997, the entire
disclosure of which is incorporated herein by reference
to the extent necessary to proper understanding. Optical
read/write systems are also described by Alan B.

30 Marchant, in "Optical Recording," Addison-Wesley
Publishing (1990).

An optical beam from the optical head 140 is
focused onto the optical medium 150 and can cause
localized heating at and near the focused spot. This

35 localized heating can modify certain properties of the

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optical medium 150 and can be coupled to the optical head
140 through the thin air gap to modify the
characteristics of the interfacing between the optical
head 140 and the medium 150.

5   This heating causes distortion in the optical
signal received by the optical head 140 and can degrade
the performance of the system. In a near-field
configuration, the distortion in the optical signals is
specially significant since the spacing between optical

10 head and the optical medium is small (i.e., less than one
wavelength). Hence, it is particularly important to
mitigate this effect in a near-field system.

       The localized heating effect can be indicated by
the signal detected by the detection module 108 in the

15 system 100 of FIG. 1. It has been found that the
distortion in the signal detected by the detection module
108 shows a dependence on the power of the light source
102 when the power is above a threshold.

       FIGs. 2A and 2B are charts of measured data

20 showing this effect. A system similar to the system 100
in FIG. 1 was used to obtain the data in FIGs. 2A and 2B.
A diode laser was used as the light source 102. The
driving current injected into the diode laser can be used
to represent the laser power. The optical medium 150 is

25 a multilayer magneto-optical ("MO") disk having a
structure as follows:

       Top dielectric/MO/SiN/Al/Substrate,

in which the top dielectric layer is about 30 to 50 nm
thick, the MO layer is about 20 to 30 nm thick, the SiN

30 layer is about 10 to 20 nm thick, and the aluminum
reflecting layer is about 50 to 60 nm. The substrate is
formed of a plastic and is about 2 mm thick.

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When the diode laser was driven at a low current of about 58.1 mA, the properties of the head/medium interface are not significantly changed. Thus, signals received by the detection module 108 remain substantially
5 constant. FIG. 2A shows three traces as a function of time at the low current. The top trace 210a is an alignment error signal ("AES") indicating the beam offset along a track direction and used for aligning/mounting the optical head, the center trace 210b is the normalized
10 tracking error signal ("NTES") indicating the beam offset across a track and used for tracking the beam, and the bottom trace 210c is a laser Doppler signal representing the variation in the axial position of the disk during operation relative to the diode laser. The AES and NTES
15 signals are typically generated by a quadrant detector in the detection module 108. The measured data indicates that, at the laser power corresponding to the driving current of 58.1 mA, the DC levels of the AES 210a and the NTES 210b essentially remain constant, uniform and
20 undistorted (i.e., a constant DC level).

As the driving current to the diode laser increases to 60.8 mA, the AES and NTES become distorted and the DC levels of the AES and the NTES vary with the laser Doppler signal. This is shown in FIG. 2B in which
25 traces 220a, 220b, and 220c represent the AES, the NTES, and the laser Doppler signal, respectively. Additional measurements indicate that such signal variation is dependent on the laser power. When the laser power is below a threshold value which corresponds to a driving
30 current of 59.3 mA, the effect of the signal variation becomes essentially negligible.

The signal variation due to the laser power will be referred to as laser power dependent signal ("LAPD") phenomena in the following description. This is
35 undesirable and should be minimized if possible. A

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variation in the NTES and AES caused by the LAPD may
falsely indicate that an on-track beam is mis-aligned
with the track and marks being read or written are off
the center of the track. In general, any feedback signal
5 passing through the interface between the optical head
and the medium is adversely affected by the LAPD, leading
to track misregistration or data jitter.

One way to mitigate this problem is to maintain
the laser power under the LAPD threshold. However, the
10 laser power cannot be too low because a certain minimum
power level is required to achieve a desired signal-to-
noise ratio during data readout and to write data in the
recording layer (e.g., a MO layer or a phase-changing
layer) during recording.

15   A more preferred solution to the problem is to
increase the threshold for the laser power dependent
variation of optical signals so that the laser power can
be increased to achieve a desired signal-to-noise ratio
but is still kept under the LAPD threshold.

20   In recognition of the above, a multilayer
structure of the optical medium is disclosed to reduce or
substantially minimize the heat transfer from the
recording layer to the interface of the optical medium
and the optical head. This reduces the temperature
25 change at the surface of the medium close to the optical
head and in effect increases the LAPD threshold.

One embodiment of the multilayer structure of the
optical medium includes one or more special power-
mitigating layers to reduce thermal coupling between the
30 optical head and the recording layer. A power-mitigating
layer may be implemented in at least two different
configurations. One configuration uses a special capping
layer formed of a material with a low thermal
conductivity and disposed between the optical head and

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the recording layer to provide thermal insulation between the optical head and the recording layer in the medium.

Another configuration of the power-mitigating layer is a highly thermally conductive layer disposed to
5 conduct the generated heat in the recording layer away from the interface of the optical head and the medium. These two types of power-mitigating layers may be used either individually or in combination.

One or more special capping layers may be formed
10 between the optical head and the recording layer. These capping layers have properties to thermally insulate the optical head from the recording layer. A capping layer may be formed of a thick and optically transparent material with a low thermal conductivity in order to
15 reduce the thermal feedback from the medium to the optical head caused by the localized heating. A material comprising at least one of a diamond-like-carbon ("DLC") material, silicon nitride or oxide materials, titanium dioxide, zirconium dioxide and others, for example, can
20 be used.

A capping layer may be characterized by finding a ratio between the thickness of the capping layer and the respective thermal conductivity. In general, this ratio should be sufficiently large to provide desired thermal
25 insulation. For example, a suitable capping layer may be configured to have a thickness-to-conductivity ratio greater than about 10^3 nm$\cdot$(J/cm$\cdot$s$\cdot$°C)$^{-1}$, and preferably greater than about 2×10^3 nm$\cdot$(J/cm$\cdot$s$\cdot$°C)$^{-1}$, and more preferably greater than 14×10^3 nm$\cdot$(J/cm$\cdot$s$\cdot$°C)$^{-1}$.

30   The above ratio may be modified to include the effect of optical absorption by multiplying the inverse of the absorption coefficient of the capping layer. The dielectric constant of a dielectric material can be generally expressed as ($ik+n$) where the imaginary part k
35 is the extinction coefficient representing the optical

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absorption of the material and n is the index of
refraction. It is desirable to have low extinction
coefficients in the dielectric layers disposed between
the recording layer and the optical head. The absorption
5 for a capping layer should be as small as possible. This
increases the LAPD threshold.

       FIG. 3A is a chart showing the effect of a SiN
capping layer formed on several glass substrate disks
with the following structure as shown in FIG. 3B:

10   Substrate/Al(50 nm)/SiN (varying
thickness)/DLC(10 nm),

where the DLC layer serves both as a protection layer and
an additional capping layer. The glass disks under test
have SiN capping layers with three different thicknesses
15 at 200 nm, 500 nm, and 1000 nm and DLCs with two
different extinction coefficients, a low k of about 0.02
and a high k of about 0.67. The measured data in FIG. 3
indicates that the LAPD threshold is the highest for the
disk with a SiN capping layer of 1000 nm thick and the
20 DLC layer with a low k and is the lowest for the disk
with a SiN capping layer of 200 nm thick and the DLC
layer with a high k.

       Two effects of the capping layers on the LAPD
threshold are evident in FIG. 3A. First, the LAPD
25 increases as the thickness of the SiN capping layer
increases. Second, LAPD threshold is strongly affected
by the extinction coefficient k of the top DLC layer: the
LAPD threshold increases as k decreases. Thus, it is
desirable to increase the thermal insulation of the
30 dielectric layers atop the recording layer (e.g.,
SiN/DLC) by increasing the thickness and reducing the
thermal conduction in order to increase the LAPD
threshold.

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Table 1 lists calculated temperature change and
measured LAPD threshold for various multilayer structures
having silicon dioxide and silicon nitride capping
layers. These multilayer structures each include a
5   plastic substrate, a 60-nm underlayer of AlCr as a
reflector, a 20-nm MO recording layer, a capping layer of
SiO_2 or SiN, and a DLC layer. The calculations are based
on a combination of a thermal model "TEMPROFILE" and an
optical model for a multilayer medium "DIFFRACT", both
10 developed by M. Mansuripur of University of Arizona.
See, for example, Applied Optics, Vol. 21, p. 666 (1983)
and Journal of Optical Society of America A, Vol. 6(5),
June, 1989, which are incorporated herein by reference.
Such a combination can include the effects of the optical
15 near-field configuration.

In particular, the DIFFRACT is used to calculate
the optical response including the absorption of a medium
with and without a SIL lens. The difference in the
calculated absorption between the two models can be used
20 to scale the laser power into TEMPROFILE. For example,
assume the reflectivity of a multilayer film is 0.2
without the SIL and 0.5 with the SIL. Thus, the presence
of the SIL reduces the absorption by 0.3. Therefore, to
model a 1 mW input power to the optical head, the power
25 value for TEMPROFILE should be 1 - 0.3 = 0.7 mW to
account for the SIL.

The results shown in Table 1 indicate that thicker
SiN layers can be more effective as capping layers, owing
to their thermal insulating ability, to increase the LAPD
30 threshold.

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TABLE 1

Stack	Reflectivity		Adj. Input Power	Max. Temp Rise	LAPD
	w/o SIL	w/ SIL	(mW)	(°C)	(mV)
Variation of SiO₂ thickness					
PC(THOM)ALCr(60)MO(20)SiO₂(80)DLC(20)	0.41	0.42	0.99	32.6	66
PC(THOM)ALCr(60)MO(20)SiO₂(110)DLC(20)	0.48	0.409	1.071	28	128
PC(THOM)ALCr(60)MO(20)SiO₂(140)DLC(20)	0.637	0.506	1.131	17.9	184
Variation of SiN Thickness					
PC(THOM)AlCr(60)MO(20)SiN(30)DLC(30)	0.212	0.517	0.695	35.3	58
PC(THOM)AlCr(60)MO(20)SiN(50)DLC(30)	0.17	0.351	0.819	40.6	48
PC(THOM)AlCr(60)MO(20)SiN(70)DLC(30)	0.337	0.253	1.084	40	55
PC(THOM)AlCr(60)MO(20)SiN(100)DLC(30)	0.559	0.454	1.105	25	68
PC(THOM)AlCr(60)MO(20)SiN(160)DLC(30)	0.562	0.684	0.878	17.7	108
PC(THOM)ALCr(60)MO(20)SiN(190)DLC(30)	0.345	0.617	0.728	20.7	95
PC(THOM)ALCr(60)MO(20)SiN(210)DLC(30)	0.179	0.496	0.683	22.2	103

The LAPD threshold and the surface temperature of
a multilayer thin film structure have a correspondence
with respect to each other. In general, as the surface
temperature rise caused by laser heating decreases, the
5 LAPD threshold increases and vice versa. This has been
established both by measurements and the above-mentioned
thermal modeling.

FIG. 4 shows the correlation between measured LAPD
threshold power values and calculated surface temperature
10 rise after 500 ns of laser illumination of 1 mW for
various stacks. The values of the LAPD threshold are
represented by voltages from a power detector that
measures the output power of the diode laser (i.e., light
source 102 in FIG. 1). FIGs. 5A and 5B further show the
15 above correlation for SiO₂ and SiN stacks, respectively.

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A power-mitigating layer for conducting the heat away from the interface of the optical head and the medium may be a highly thermally conductive layer placed between the recording layer and the optical head so that

5 the thermal feedback to the optical head can be reduced by laterally dissipating the heat. Since such a thermally conductive layer is formed in the path of a read/write beam, the material should be optically transparent at the operating wavelength. Dielectric

10 materials and/or thin metallic layers (e.g., less than 10 nm thick) may be used for this purpose. A layer of aluminum nitride, for example, can be configured to have a thermal conductivity of about 5 to 7 times greater than that of a SiN layer and hence can be used to form such a

15 transparent dielectric layer. For thin transparent metallic layers, suitable materials may include Ag, Au, or other metals.

Another way of implementing a thermally conductive power-mitigating layer is on the other side of the

20 recording layer away from the optical head. Such a power-mitigating layer reduces the amount of heat to the optical head side of the recording layer. Such a layer does not have to be optically transparent and in general can be any material that has a high thermal conductivity,

25 such as Ag, Au, Cu, Al, etc. The reflector layer under the recording layer, for example, can be configured to have a high thermal conductivity to function as a conductive power-mitigating layer. In one implementation, the thermal conductivity of the reflector

30 layer may be higher than that of the layers above the recording layer in order to extract a significant portion of the heat generated in the recording layer.

The above two ways of forming thermally conductive power-mitigating layers can be used individually or in

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combination depending the specific requirements of an
application.

Moreover, a capping layer and a thermally
conductive layer can be combined in a multilayer medium
5   to increase the LAPD threshold. For example, such a
combination may be used to form the following multilayer
structure:

Substrate/Reflector/MO/Capping layer/Thin metal/DLC,

where the thin metal layer is a conductive power-
10   mitigating layer and is optically transparent.
Alternatively, the thin metal layer may be substitute by
a transparent dielectric layer as the conductive power-
mitigating layer. In addition, the reflector layer may
be formed of a highly conductive layer to serve as an
15   additional conductive power-mitigating layer. This is
illustrated in FIG. 6.

Multilayer stacks with different underlayers and
capping layers have been used to investigate the effect
of the thermal conductivity of an underlayer. The
20   following two stack structures have been tested:

Stack 1:   APO/AlTi(50)/MO(20)/SiN(40)/DLC(10); and
Stack 2:   APO/AlTi(50)/SiN(20)/MO(20)/SiN(120)DLC(10),

in which APO is an amorphous poly-olefin (a plastic)
substrate and AlTi is the underlayer that is optically
25   reflective. The content of Ti can be varied to change
the thermal conductivity of the 50-nm thick AlTi
underlayer. Table 2 shows the measured thermal
conductivities for different Ti contents. The thermal
conductivity increases as the Ti content decreases.

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TABLE 2

%Ti	K(W/cm°C)
2	0.40
7	0.18
10	0.13
25	0.05

FIG. 7A shows the calculated surface temperatures
after 500 ns of illumination of a laser beam at 1 mW for
various disks based on the stack 1 with a thin SiN
capping layer and stack 2 with a thick SiN capping layer.
The surface temperature reduces as the content of the Ti
decreases.

The thickness of a given underlayer can also
affect the LAPD value, or equivalently the top surface
temperature of a multilayer medium. FIG. 7B shows the
calculated surface temperature after 500 ns of
illumination of laser power at 1 mW for the above
multilayer stack 1 with different Ti content and
different thickness values of the AlTi underlayer. The
data indicates that the surface temperature reduces as
the thickness of the AlTi underlayer increases. In
addition, the effect of thermal conductivity of the
underlayer on the surface temperature or the LAPD is more
significant than that of the thickness of the underlayer.

Although the present invention has been described
in detail with reference to the preferred embodiments,
various modifications and enhancements may be made
without departing from the spirit and scope of the
invention. For example, various techniques described
above may be combined to increase the LAPD threshold of a
multilayer medium. Other materials that are different
from what have been disclosed may be used to form a
desired multilayer medium. Although a hemispherical SIL

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is used as an exemplary near-field lens, it should be understood that the same basic principles apply to other types of near-field lenses or other near-field optical elements such as a solid immersion mirror or a high-index

5 material with a diffractive optical element (e.g., lens). See, Lee et al., "Feasibility study on near field optical memory using a catadioptric optical system," Optical Data Storage, 1998 Technical Digest Series, Vol. 8 and Japanese laid-open patent application No. 8-245053 by

10 Hatakoshi et al., which are incorporated herein by reference. These and other variations are intended to be fully encompassed by the following claims.

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What is claimed is:

     1.   A method of reducing thermal feedback from an optical medium to an optical head which couples light to said optical medium and is spaced from said optical
5 medium by a distance less than one wavelength of said light, comprising:

     providing a recording layer in said optical medium that is operable to absorb said light to produce a change in said recording layer for storing data; and
10   reducing conduction of heat generated by said absorption of said light in said recording layer towards said optical head by placing at least one power-mitigating layer relative to said recording layer in said optical medium.

15   2.   A method as in claim 1, further comprising configuring said at least one power-mitigating layer to be thermally insulating so as to reduce said conduction of said heat towards said optical head, wherein said at least one power-mitigating layer is optically transparent
20 to said light and is disposed in said optical medium between said optical head and said recording layer.

     3.   A method as in claim 2, wherein said power-mitigating layer includes a dielectric layer of predetermined thickness and low thermal conductivity.

25   4.   A method as in claim 3, wherein said dielectric layer is configured to have a ratio of said thickness over said thermal conductivity greater than about 10^3 nm· $(J/cm \cdot s \cdot °C)^{-1}$.

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5.   A method as in claim 3, wherein said
dielectric layer is formed of a material selected from
silicon nitride, silicon dioxide, titanium dioxide or
zirconium dioxide, or a diamond-like-carbon material.

5   6.   A method as in claim 1, further comprising
configuring said at least one power-mitigating layer to
have a high thermal conductivity so as to conduct at
least a portion of said heat away from said optical head.

7.   A method as in claim 6, wherein said power-
10 mitigating layer is disposed between said optical head
and said recording layer.

8.   A method as in claim 7, wherein said power-
mitigating layer includes an aluminum nitride or a thin
and optically transparent metallic film formed of Ag or
15 Au.

9.   A method as in claim 8, wherein said metallic
film is less than 10 nm in thickness.

10.   A method as in claim 6, wherein said power-
mitigating layer is disposed at one side of said
20 recording layer that is opposite to said optical head.

11.   A method as in claim 6, wherein said power-
mitigating layer is configured to conduct said portion of
said heat laterally along said power-mitigating layer.

12.   A method for constructing an optical storage
25 system having an optical medium and an optical head which
couples light to said optical medium and is spaced from
said optical medium by a distance less than one
wavelength of said light and for reducing thermal

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feedback from said optical medium to said optical head, comprising:

      providing a recording layer in said optical medium that absorbs said light to produce a change in
5 said recording layer for storing data; and

      placing at least one power-mitigating layer relative to said recording layer in said optical medium to change a threshold power of said light indicative of said thermal feedback, wherein a received optical signal
10 by said optical head from said optical medium has a dependence on a power of said light when said power is greater than said threshold power and said dependence is substantially minimized when said power is less than said threshold power; and

15   configuring said at least one power-mitigating layer to reduce conduction of heat generated by said absorption of said light in said recording layer towards said optical head and to increase said threshold power.

20   13. A method as in claim 12, further comprising configuring said at least one power-mitigating layer to be thermally insulating so as to reduce said conduction of said heat towards said optical head, wherein said at least one power-mitigating layer is optically transparent
25 to said light and is disposed in said optical medium between said optical head and said recording layer.

      14. A method as in claim 13, wherein said power-mitigating layer includes a dielectric layer of predetermined thickness and low thermal conductivity.

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15. A method as in claim 14, wherein said dielectric layer is configured to have a ratio of said thickness over said thermal conductivity greater than about 10^3 nm·$(J/cm·s·°C)^{-1}$.

5   16. A method as in claim 14, wherein said dielectric layer is formed of a material selected from silicon nitride, silicon dioxide, titanium dioxide or zirconium dioxide, or a diamond-like-carbon material.

17. A method as in claim 12, further comprising
10 configuring said at least one power-mitigating layer to have a high thermal conductivity so as to conduct at least a portion of said heat away from said optical head.

18. A method as in claim 17, wherein said power-mitigating layer is disposed between said optical head
15 and said recording layer.

19. A method as in claim 18, wherein said power-mitigating layer includes an aluminum nitride or a thin and optically transparent metallic film formed of Ag or Au.

20   20. A method as in claim 19, wherein said metallic film is less than 10 nm in thickness.

21. A method as in claim 17, wherein said power-mitigating layer is disposed at one side of said recording layer that is opposite to said optical head.

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22. A system for optical data storage, configured
to perform at least one of recording or reproducing
information from an optical medium adapted for use with
an optical source, said optical medium comprising:

5   a reflective layer formed on a substrate and
configured to reflect light at a specified wavelength or
a spectral range produced by said optical source;
           a recording layer formed over said reflective
layer and configured to interact with said light to
10   record data or to imprint data on said light;
           a surface layer formed relative to said
recording layer to provide an interface for coupling said
light between said recording layer and said optical
source;
15   at least one power-mitigating layer located
relative to said recording layer and configured to reduce
conduction of heat generated by absorption of said light
in said recording layer towards said surface layer,
           wherein said at least one power-mitigating
20   layer is configured to change a threshold power of said
light indicative of an amount of said conducted from
recording layer to said surface layer, wherein a
reflected optical signal from said reflective layer to
said surface layer has a dependence on a power of said
25   light when said power is greater than said threshold
power and said dependence is substantially minimized when
said power is less than said threshold power.

23. A system as in claim 22, wherein said at
least one power-mitigating layer is thermally insulating
30   so as to reduce said conduction of said heat towards said
surface layer and is disposed between said surface layer
and said recording layer to transmit said light.

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24.   A system as in claim 23, wherein said power-mitigating layer includes a dielectric layer of predetermined thickness and low thermal conductivity.

25.   A system as in claim 24, wherein said
5   dielectric layer is configured to have a ratio of said thickness over said thermal conductivity greater than about 10^3 nm$\cdot$(J/cm$\cdot$s$\cdot$°C)$^{-1}$.

26.   A system as in claim 24, wherein said dielectric layer is formed of a material selected from
10   silicon nitride, silicon dioxide, titanium dioxide or zirconium dioxide, or a diamond-like-carbon material.

27.   A system as in claim 22, wherein said at least one power-mitigating layer has a high thermal conductivity so as to conduct at least a portion of said
15   heat away from said surface layer.

28.   A system as in claim 27, wherein said power-mitigating layer is disposed between said surface layer and said recording layer.

29.   A system as in claim 28, wherein said power-
20   mitigating layer includes an aluminum nitride or a thin and optically transparent metallic film formed of Ag or Au.

30.   A system as in claim 29, wherein said metallic film is less than 10 nm in thickness.

25   31.   A system as in claim 27, wherein said power-mitigating layer is disposed at one side of said recording layer that is opposite to said surface layer.

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32. A system as in claim 22, wherein said power-mitigating layer includes a dielectric layer of predetermined thickness and low thermal conductivity.

33. A system as in claim 32, wherein said
5 dielectric layer is configured to have a ratio of said thickness over said thermal conductivity greater than about 10^3 nm$\cdot$(J/cm$\cdot$s$\cdot$°C)$^{-1}$.

34. A system as in claim 32, wherein said dielectric layer is formed of a material selected from
10 silicon nitride, silicon dioxide, titanium dioxide or zirconium dioxide, or a diamond-like-carbon material.

35. A system for optical data storage, configured to perform at least one of recording or reproducing information from an optical medium adapted for use with
15 an optical source, said optical medium comprising:
            a reflective layer formed on a substrate and configured to reflect light at a specified wavelength or a spectral range produced by said optical source;
            a recording layer formed over said reflective
20 layer and configured to interact with said light to record data or to imprint data on said light;
            a surface layer formed relative to said recording layer to provide an interface for coupling said light between said recording layer and said optical
25 source;
            a capping layer formed over said recording layer by an optically transparent material with a predetermined low thermal conductivity and a predetermined thickness to reduce conduction of heat
30 generated by absorption of said light in said recording layer towards said surface layer; and

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a thermal conductive layer formed over said capping layer configured to have a predetermined high thermal conductivity to laterally transfer at least a portion of heat conducted from said capping layer along 5 said thermal conductive layer, thereby reducing conduction of heat to said surface layer.

36. A system as in claim 35, wherein said reflective layer is configured to have a prespecified high thermal conductivity to conduct at least a portion 10 of heat generated in said recording layer away from said recording layer, thereby reducing conduction of heat to said surface layer.

37. A method of configuring an optical medium to reduce thermal feedback to an optical head which couples 15 light to said optical medium and is spaced from said optical medium by a distance less than one wavelength of said light, comprising:
       providing a recording layer having a first side and a second side in said optical medium that is 20 operable to absorb said light from said first side to produce a change in said recording layer for storing data;
       providing a reflective layer formed on said second side of said recording layer to reflect said light 25 towards said first side;
       configuring said reflective layer to have a high thermal conductivity to conduct at least a portion of heat generated in said recording layer away from said first side of said recording layer;
30   forming a thermal insulating layer on said first side of said recording layer with predetermined thickness and low thermal conductivity to at least

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partially prevent said heat from being conducted toward
said optical head; and

        forming a transparent thermal conductive
layer over said thermal insulating layer to conduct heat
5   from said thermal insulating layer laterally along said
thermal conductive layer, thereby reducing conduction of
heat towards said optical head.

        38.   A method as in claim 37, wherein said thermal
insulating layer is configured to have a ratio of said
10 thickness over said low thermal conductivity greater than
about 10^3 nm$\cdot$ (J/cm$\cdot$s$\cdot$°C)$^{-1}$.

        39.   A method as in claim 38, wherein said ratio
of said thickness over said low thermal conductivity is
greater than about 2 x 10^3 nm$\cdot$ (J/cm$\cdot$s$\cdot$°C)$^{-1}$.

15   40.   A method as in claim 39, wherein said ratio
of said thickness over said low thermal conductivity is
greater than about 14 x 10^3 nm$\cdot$ (J/cm$\cdot$s$\cdot$°C)$^{-1}$..

        41.   A method as in claim 37, wherein said thermal
insulating layer includes a dielectric layer which is
20 formed of a material selected from silicon nitride,
silicon dioxide, titanium dioxide or zirconium dioxide,
or a diamond-like-carbon material.

        42.   A method as in claim 37, wherein said
transparent thermal conductive layer includes an aluminum
25 nitride or a thin and metallic film formed of Ag or Au.

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43. A method of operating an optical disk, comprising:

orienting an optical head in a near field optical configuration, in which the optical head is within one
5 wavelength of the optical medium; and

avoiding an optical distortion in an interface between the optical head and the medium that is caused by operating over a threshold driving power to the laser.

44. A method as in claim 43 wherein said avoiding
10 comprises maintaining a power of the laser below said threshold.

45. A method as in claim 43 wherein said distortion is caused by localized heating in the medium.

15   46. A method as in claim 43 wherein said avoiding comprises increasing a threshold for a laser power dependent variation of the optical signal.

47. A method as in claim 46 wherein said increasing a threshold comprises using a special
20 structure on the disk.

48. A method as in claim 47 wherein said special layer on the disk comprises a layer which minimizes heat transfer from a recording layer on the disk to said interface between the optical medium and the optical
25 head.

49. A method as in claim 47 wherein said special structure is a heat insulating layer.

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50. A method as in claim 49 wherein said heat insulating layer includes power mitigating layers that reduce thermal coupling between the head and optical medium.

5   51. A method as in claim 47 wherein said special structure includes thermally conductive layers.

52. A method as in claim 51 wherein said thermally conductive layers conduct generated heat away from the interface.

10   53. An optical medium, comprising:
at least one recording layer, having a recording portion therein adapted for interfacing with an optical laser using a near field configuration in which the optical laser is placed within one wavelength of an
15 optical recording medium; and
means, on said optical medium, for reducing a laser power dependent signal effect in said optical medium.

54. An optical medium as in claim 53 wherein said
20 laser power dependent compensating means comprise a special compensating layer on the optical medium which compensates for said laser power dependent signal.

55. A medium as in claim 54 wherein said layer is an insulating layer.

25   56. A medium as in claim 55 wherein said layer is a heat spreading layer.

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57. A medium as in claim 53 wherein said means compensates for localized heating effects caused by the laser power.

58. A medium as in claim 53 wherein the medium
5 has a multiple layer structure which minimizes heat transfer from the recording layer to interface between the optical medium and the optical head.

59. A medium as in claim 58 wherein at least one of said layers is a power mitigating layer which prevents
10 heat transfer from the recording layer to said interface.

60. A medium as in claim 59 wherein said mitigating layer is a capping layer formed of a material with a low thermal conductivity.

61. A medium as in claim 59 wherein said power
15 mitigating layer is a thermally conductive layer that conducts generated heat in the conducting layer to another location.

62. A medium as in claim 60 wherein said capping layer has thickness that is effective to provide a
20 desired thermal insulation.

63. A medium as in claim 62 wherein said thickness also takes into account optical absorption of the capping layer.

64. A medium as in claim 62 wherein the capping
25 layer has a thickness-to-conductivity ratio greater than 10^3 nanometers .J/cm.s.°C-1.

65. A medium as in claim 59 wherein said capping
layer is formed of silicon nitride.

66. A medium as in claim 61 wherein said capping
layer is formed of an optically transparent conducting
5   material.

67. A medium as in claim 66 wherein said
materials include a thin metallic layer less than 10
nanometers thick.

68. A medium as in claim 61 wherein said
10   thermally conductive power mitigating layer is on an
opposite side of the medium, facing away from an
interface between said recording medium and said optical
head.

69. A medium as in claim 60 wherein said power
15   mitigating layer is a thermally conductive layer that
conducts generated heat in the conducting layer to
another location.

70. A method of avoiding laser power dependent
heating effects, comprising:
20   placing an optical medium and an optical laser in
close proximity to one another, with said optical laser
being located at or closer than one wavelength relative
to said optical medium; and
        modifying a structure of said optical medium to
25   reduce an effect of laser power dependent heating.

71. A method as in claim 70 wherein said
modifying comprises placing an insulating layer on said
optical medium to insulate between said interface
between said optical disk and said optical head.

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72. A method as in claim 70 wherein said modifying comprises placing an optically conductive layer in a location to spread heat created in a recording layer.

5   73. A method as in claim 72 wherein said layer is a layer that is optically transparent at a wavelength of said laser, located between said interface and said laser.

74. A method as in claim 72 wherein said layer is
10 located on an opposite side of said optical disk.

75. A method of recording on an optical disk, comprising:
       placing an optical laser in close proximity to an optical disk;
15   determining a laser power dependent threshold, at which laser power causes distortion over an interface between said laser and said optical medium; and
       increasing the laser power dependent threshold.

76. A method as in claim 75 wherein said
20 increasing comprises adding a layer to the optical medium to increase the power dependent threshold.

77. A device as in claim 76 wherein said layer comprises an insulating layer.

78. A method as in claim 76 wherein said layer
25 comprises a conductive layer.

79. A method as in claim 78 wherein said conductive layer is on an opposite side of the disk, away from said interface.
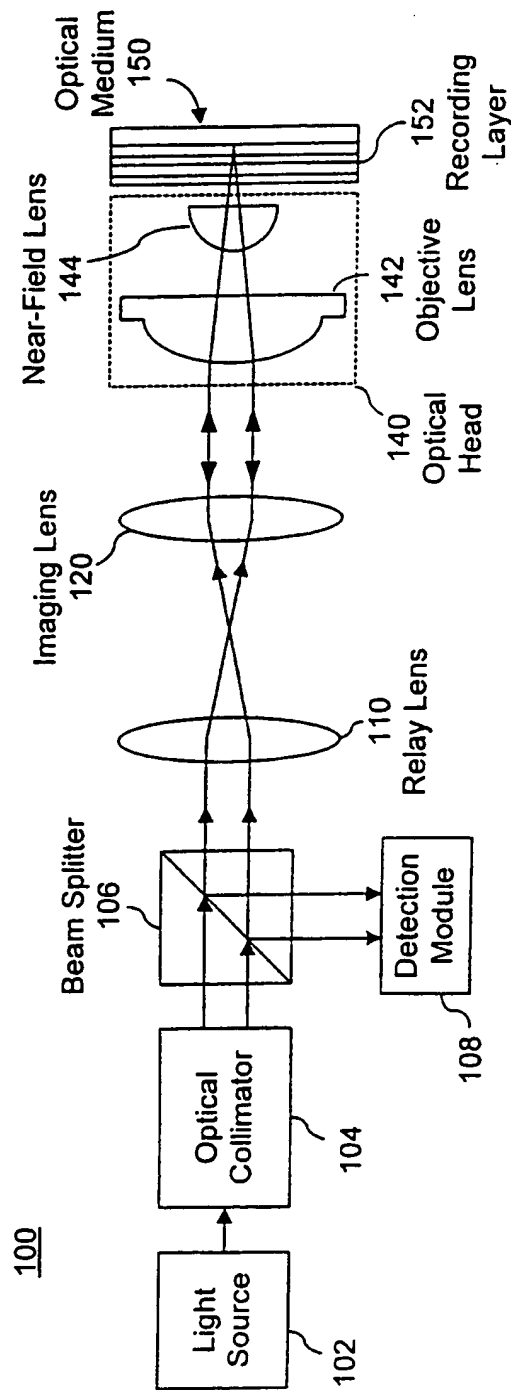
FIG. 1

FIG. 2B

Signal Amplitude (a.u.)

220a
220b
220c

100ms　500ms　0.3　250ms

→ time

A4 C 440 U

FIG. 2A

Signal Amplitude (a.u.)
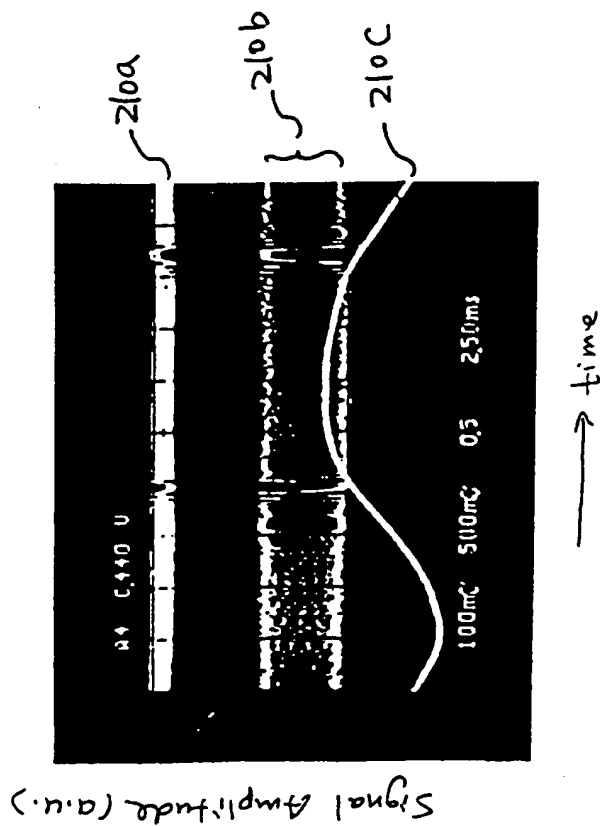
210a
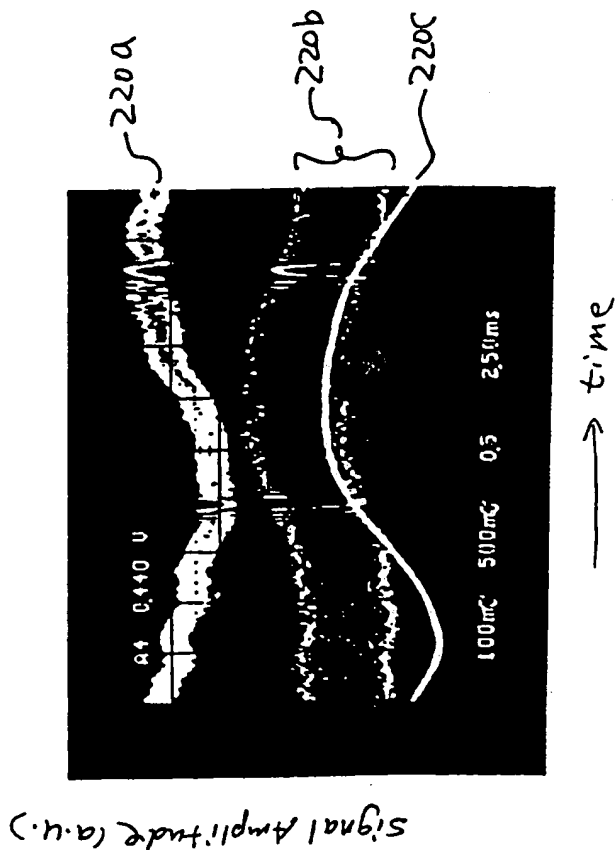210b
210c

100ms　500ms　0.3　250ms

→ time

A4 C 440 U

FIG. 3A   LAPD threshold on glass disks with different thickness of SiN Capping layer with 2 different Carbon over coats and 50nm Al absorbing layer
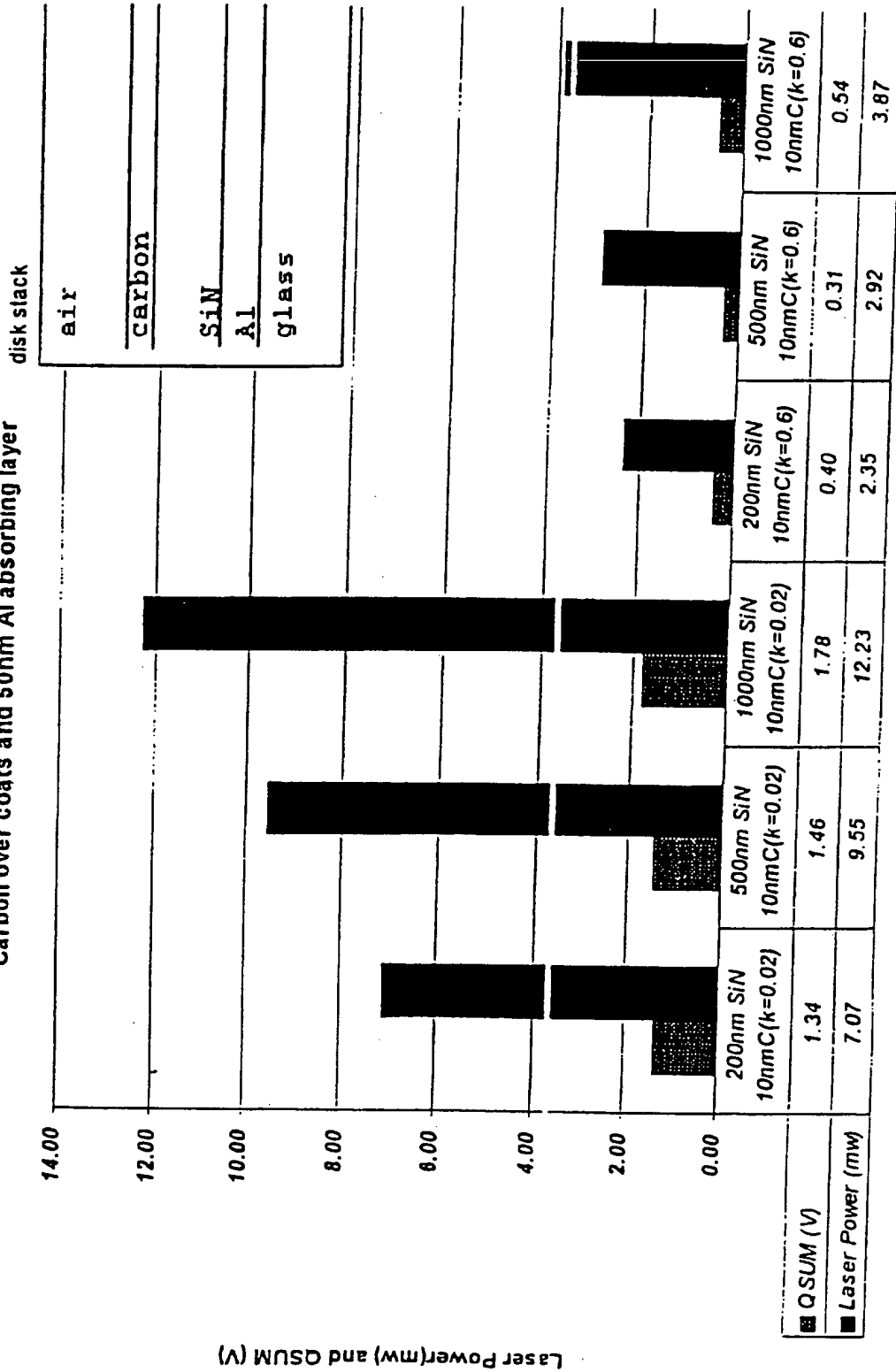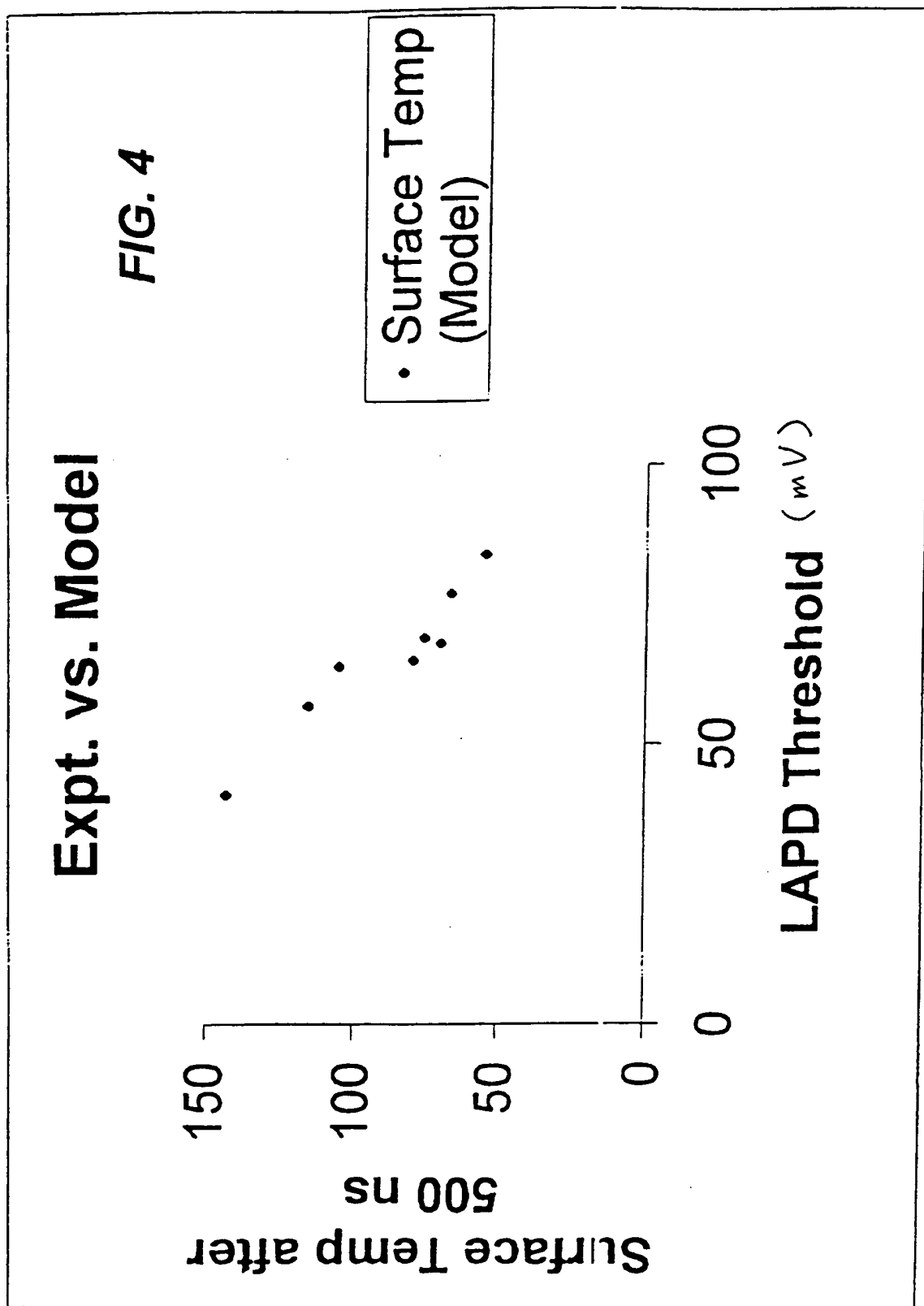
air
carbon
SiN
Al
glass

disk stack

Laser Power(mw) and QSUM (V)

	200nm SiN 10nmC(k=0.02)	500nm SiN 10nmC(k=0.02)	1000nm SiN 10nmC(k=0.02)	200nm SiN 10nmC(k=0.6)	500nm SiN 10nmC(k=0.6)	1000nm SiN 10nmC(k=0.6)
▨ QSUM (V)	1.34	1.46	1.78	0.40	0.31	0.54
▪ Laser Power (mw)	7.07	9.55	12.23	2.35	2.92	3.87

14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00

FIG. 6

| DLC Layer |
| Conductive Power-Mitigating Layer |
| Capping Power-Mitigating Layer |
| MO Layer |
| Reflector |
| Substrate |

FIG. 3B

| DLC (10nm) |
| SiN |
| Al (50nm) |
| Substrate |

FIG. 4

SiO2 Capping Disks - Model vs. Expt

FIG. 5A
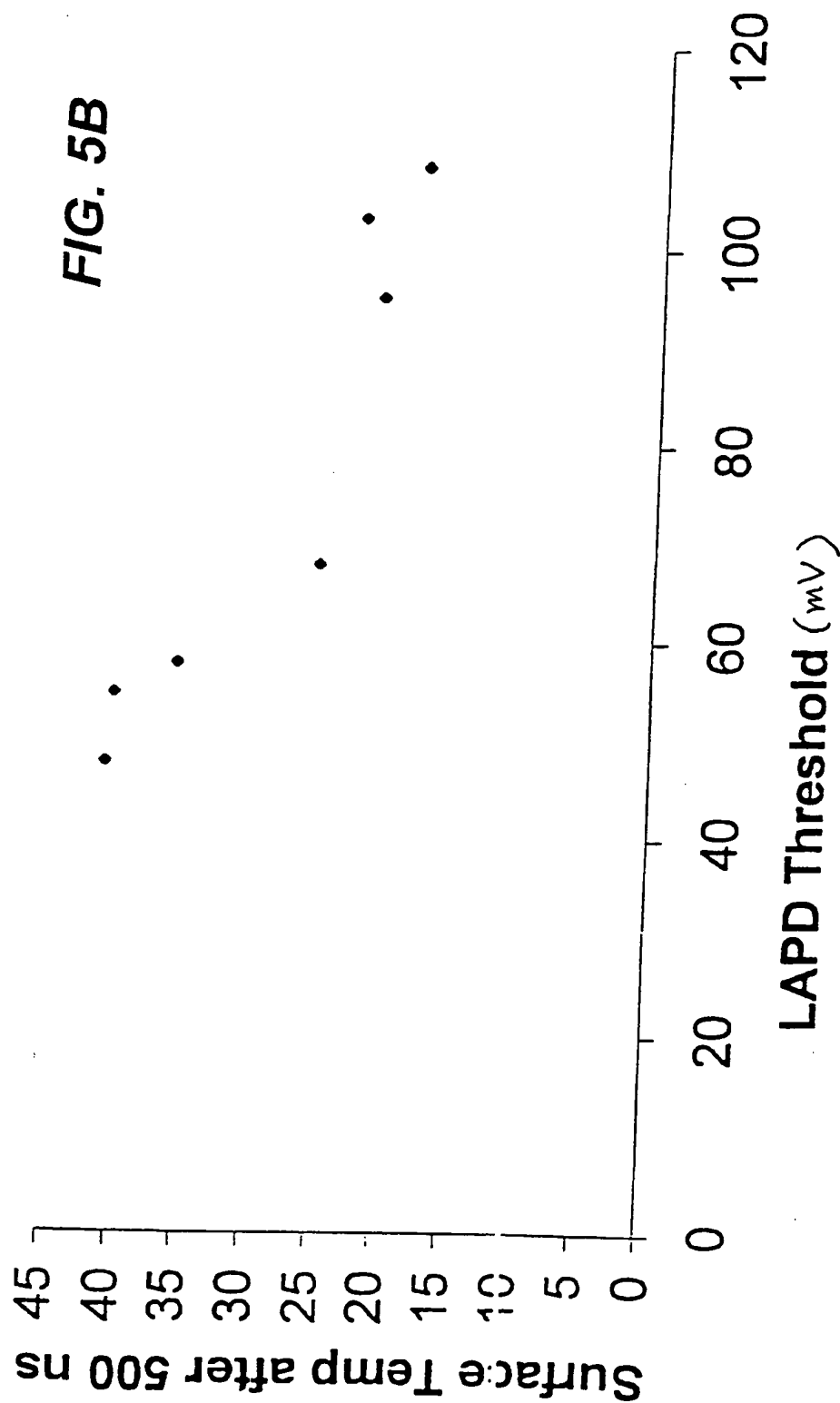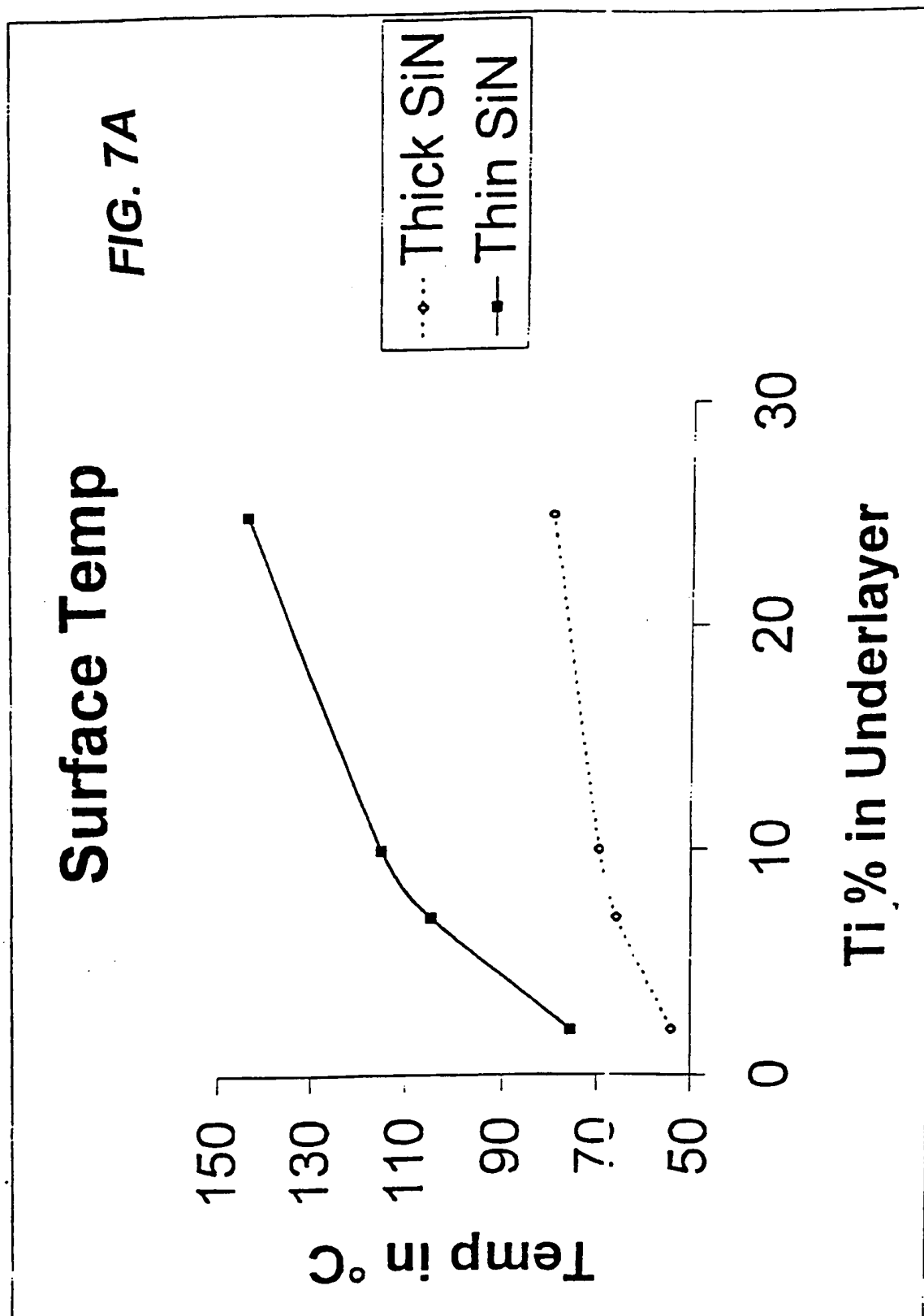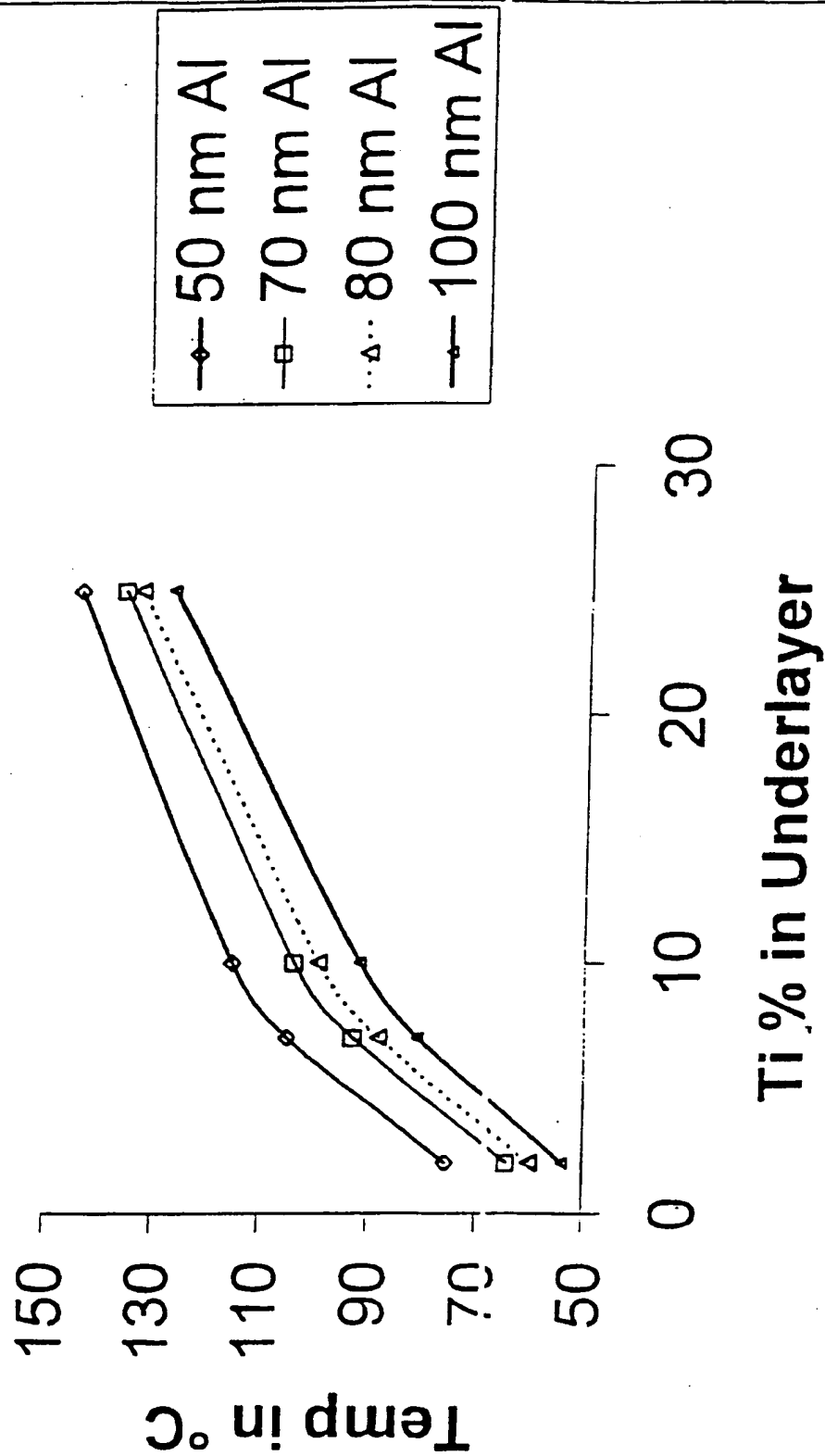
LAPD Threshold (mV)

Surface Temp after 500 ns

FIG. 5B

SiN Capping Disks - Model vs. Expt

Surface Temp after 500 ns

LAPD Threshold (mV)

FIG. 7A

Surface Temp

FIG. 7B

Surface Temp

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :G11BB 5/66, 5/74, 11/00; B32B 5/16
US CL :Please See Extra Sheet.
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : Please See Extra Sheet.

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 09-044904 A (ABIKO) 14 February 1997, entire document, particularly sections 0020-0025 and 0035-0053.	1-7,10-18, 53-64,66 70-79
X,P	US 5,904,819 A (ABIKO) 18 May 1999, examples	1-7,10-18, 53-64,66, 70-79
X ---- Y	US 5,633,746 A (SEKIYA et al.) 27 May 1997, Entire document, specifically figure 14 and related text.	1-7,10-18, 21-28, 31-79 --------- 1-79

☒ Further documents are listed in the continuation of Box C.   ☐ See patent family annex.

*	Special categories of cited documents:
"A"	document defining the general state of the art which is not considered to be of particular relevance
"E"	earlier document published on or after the international filing date
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O"	document referring to an oral disclosure, use, exhibition or other means
"P"	document published prior to the international filing date but later than the priority date claimed

"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&"	document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
19 AUGUST 1999	**2 1 OCT 1999**

Name and mailing address of the ISA/US	Authorized officer
Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	MARTIN J. ANGEBRANNDT
Facsimile No. (703) 305-3230	Telephone No. (703) 308-0661

Form PCT/ISA/210 (second sheet)(July 1992)*

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X ---- Y	US 5,656,370 A (MURAKAMI et al.) 12 August 1997, entire document, particularly col/line 10/61-11/15, 4/45-5/15, 3/33-44.	1-7,10-18, 53-64,66, 70-79 --------- 1-79
X	US 5,604,003 A (COOMBS et al.) 18 February 1997, example 2	1-8,10-19, 21-29, 31-79
X	US 5,565,278 A (BIRUKAWA et al.) 15 October 1996, entire document, particularly col 5/lines 24-33.	1-7,10-18, 53-64,66, 70-79
A	US 5,731,049 A (TAILHADES et al.) 24 March 1998, entire document, particularly col 4/lines 34-39.	1-79
A	US 5,497,359 A (MAMIN et al.) 05 March 1996, entire document, particularly col. 7/lines 12-30	1-79
A	US 5,125,750 A (CORLE et al.) 30 June 1992, entire document.	1-79
A	US 5,577,021 A (NAKATANI et al.) 19 November 1996, entire document	1-79
A	US 5,712,833 A (OGIHARA et al.) 27 January 1998, entire document	1-79
A	US 5,560,998 A (OYAMATSU et al) 01 October 1996, entire document	1-79

A. CLASSIFICATION OF SUBJECT MATTER:
US CL :

430/270.13, 271.1, 273.1, 275.1, 945; 369/283, 275.2, 275.5; 428/65.5, 694RL, 694DE, 694TP, 694PR, 694TC

B. FIELDS SEARCHED
Minimum documentation searched
Classification System: U.S.

430/270.13, 271.1, 273.1, 275.1, 945; 369/283, 275.2, 275.5; 428/65.5, 694RL, 694DE, 694TP, 694PR, 694TC